Impacts and Adaptive Responses:

Energy

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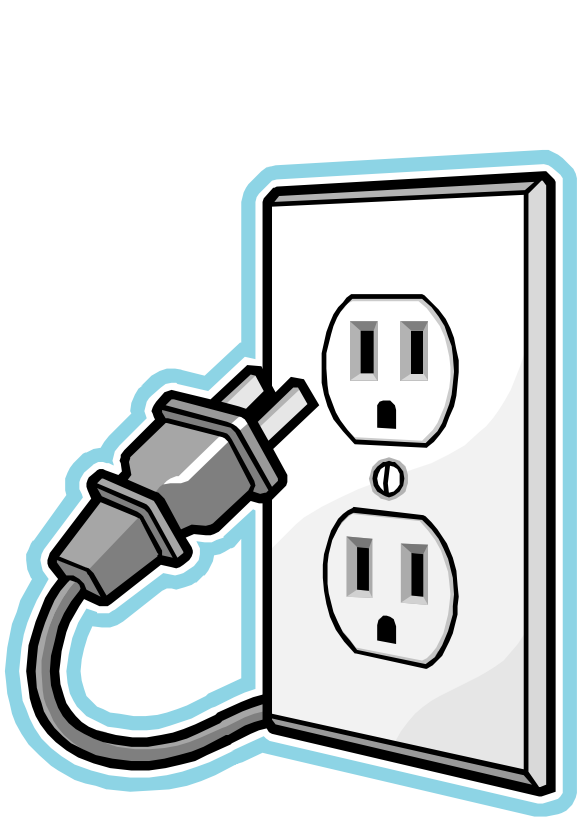
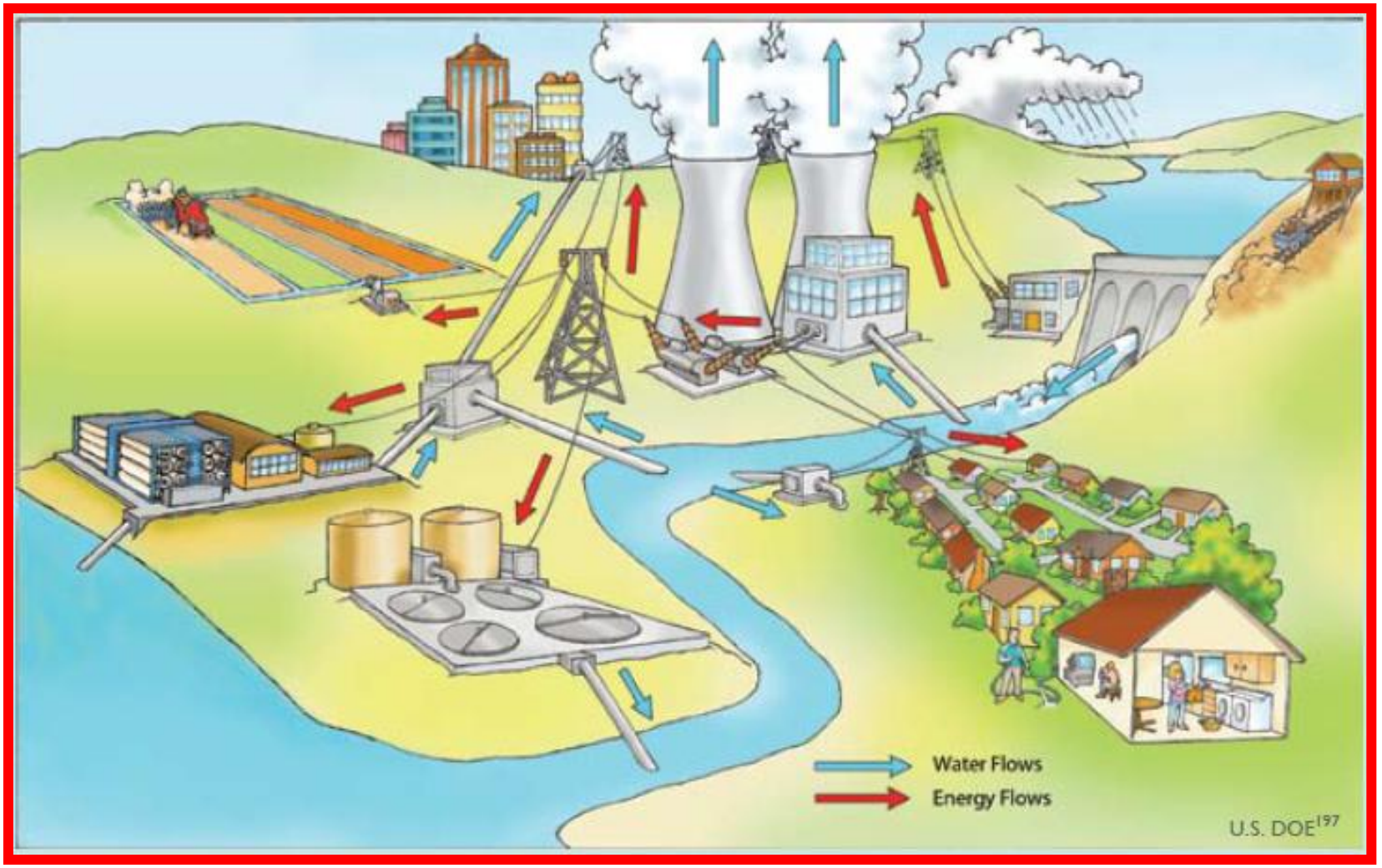
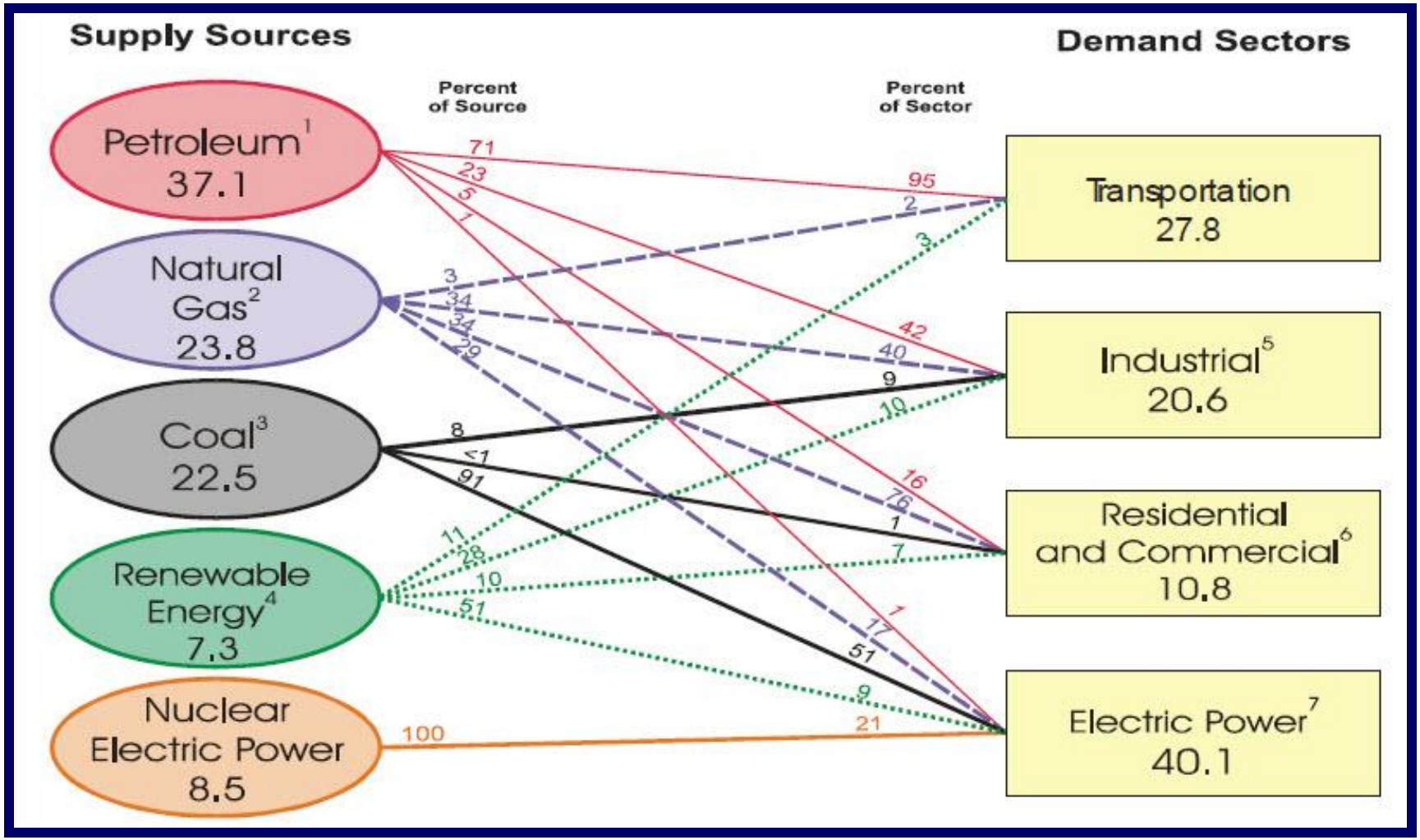
Interrelationship between Water and Energy





Intimate Connection between Energy and Water

U.S. Primary Energy Consumption by Source and Sector, 2008 (Quadrillion Btu)



Source: DOE/EIA

99.2 Quadrillion BTU

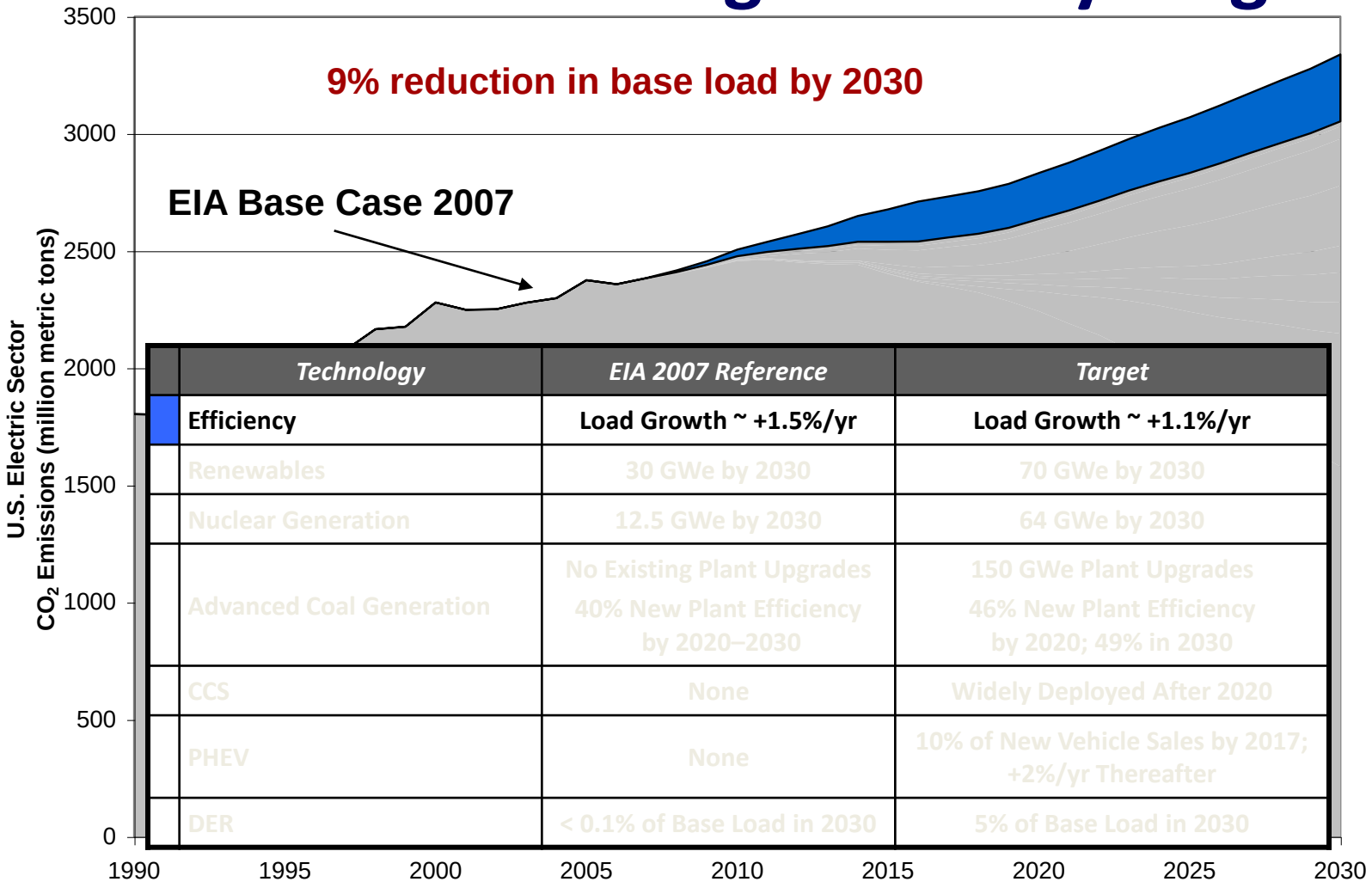
Sector

- Transportation
- Industrial
- Residential
- Electricity

End Use

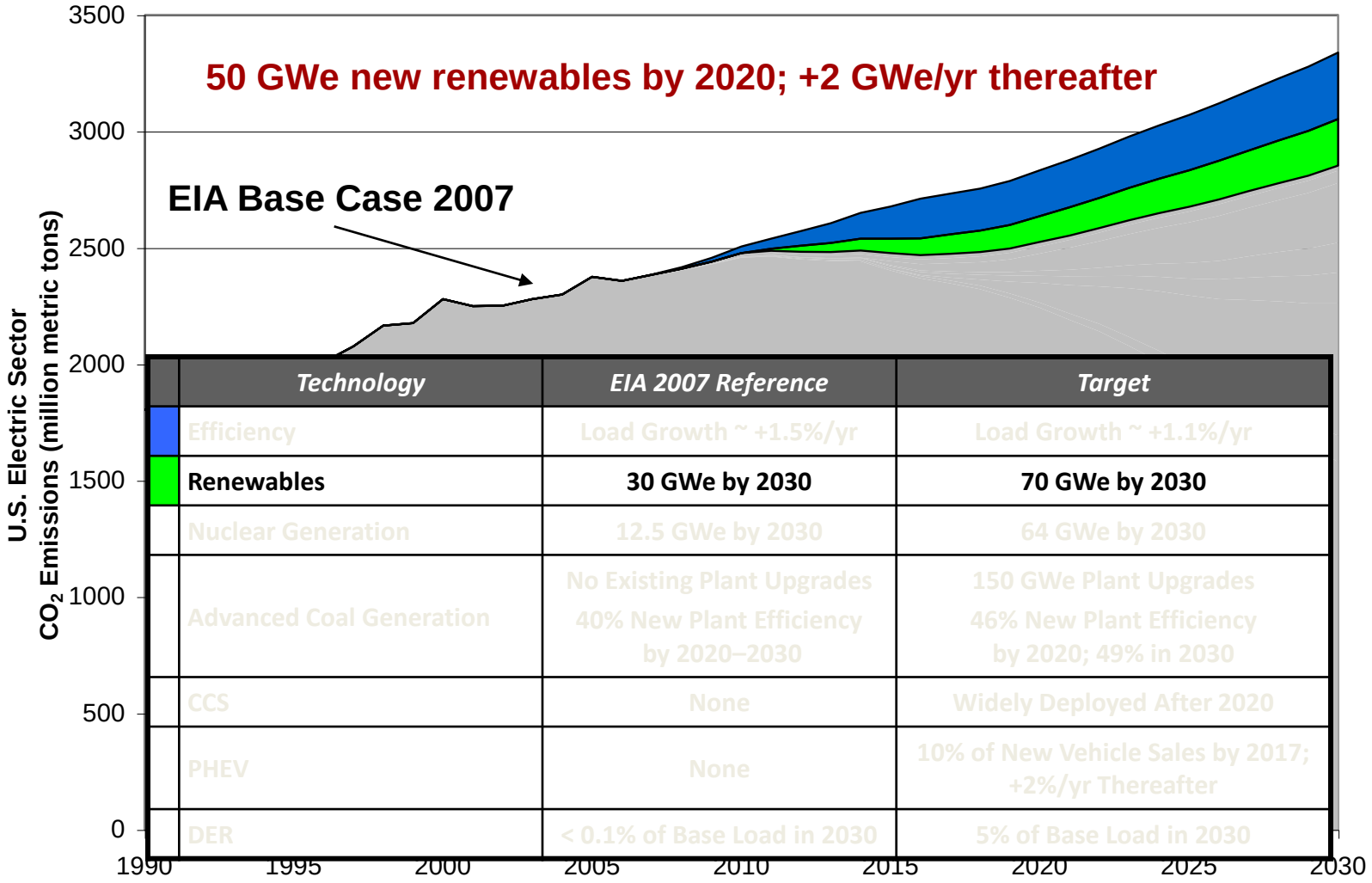
- Space heating
- Air conditioning
- Water/waste pumping
- Refrigeration
- PHEVs
- Other (appliances)

Benefit of Achieving Efficiency Target



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

Benefit of Achieving Renewables Target



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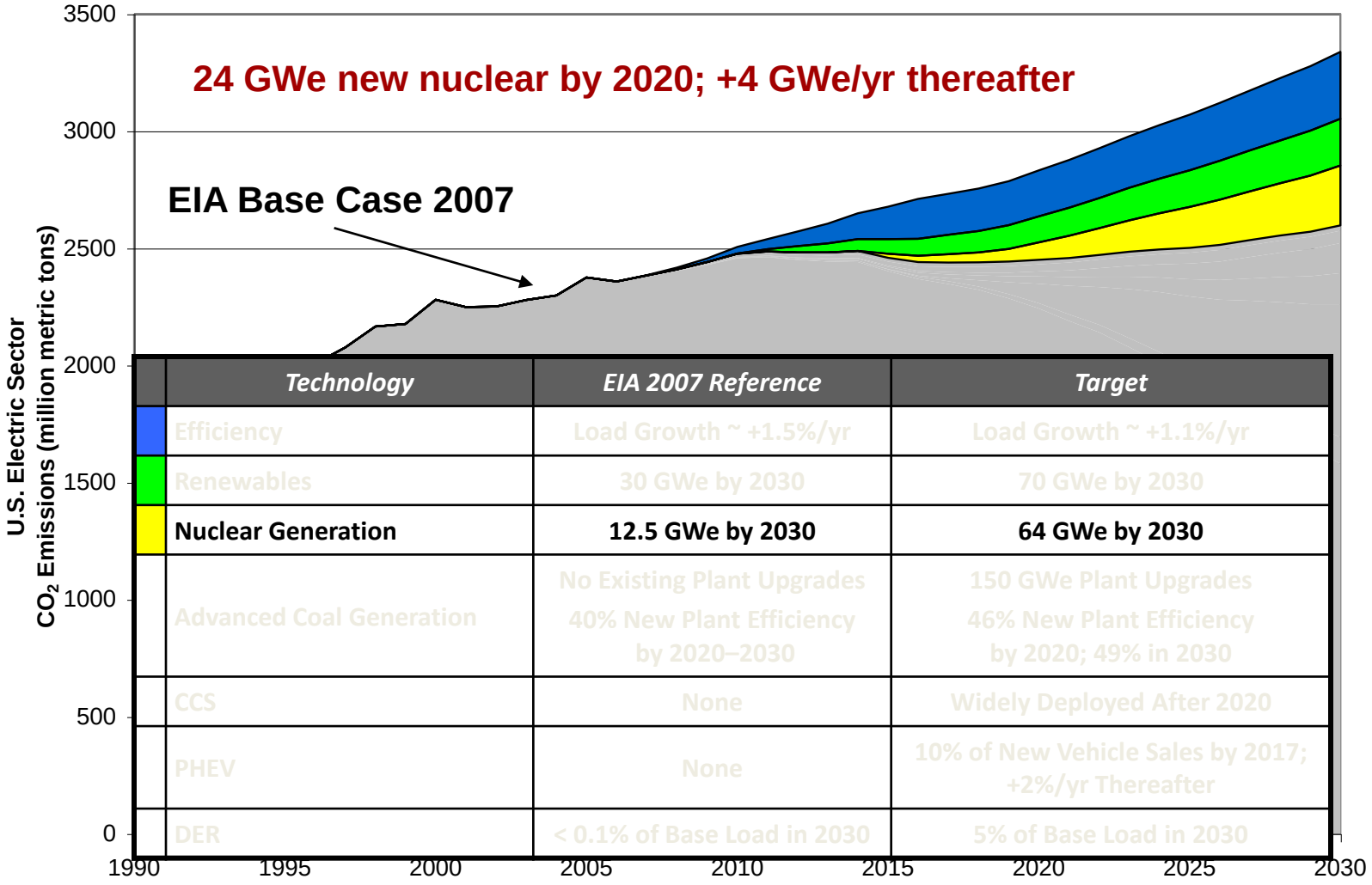
Benefit of Achieving Nuclear Generation Target



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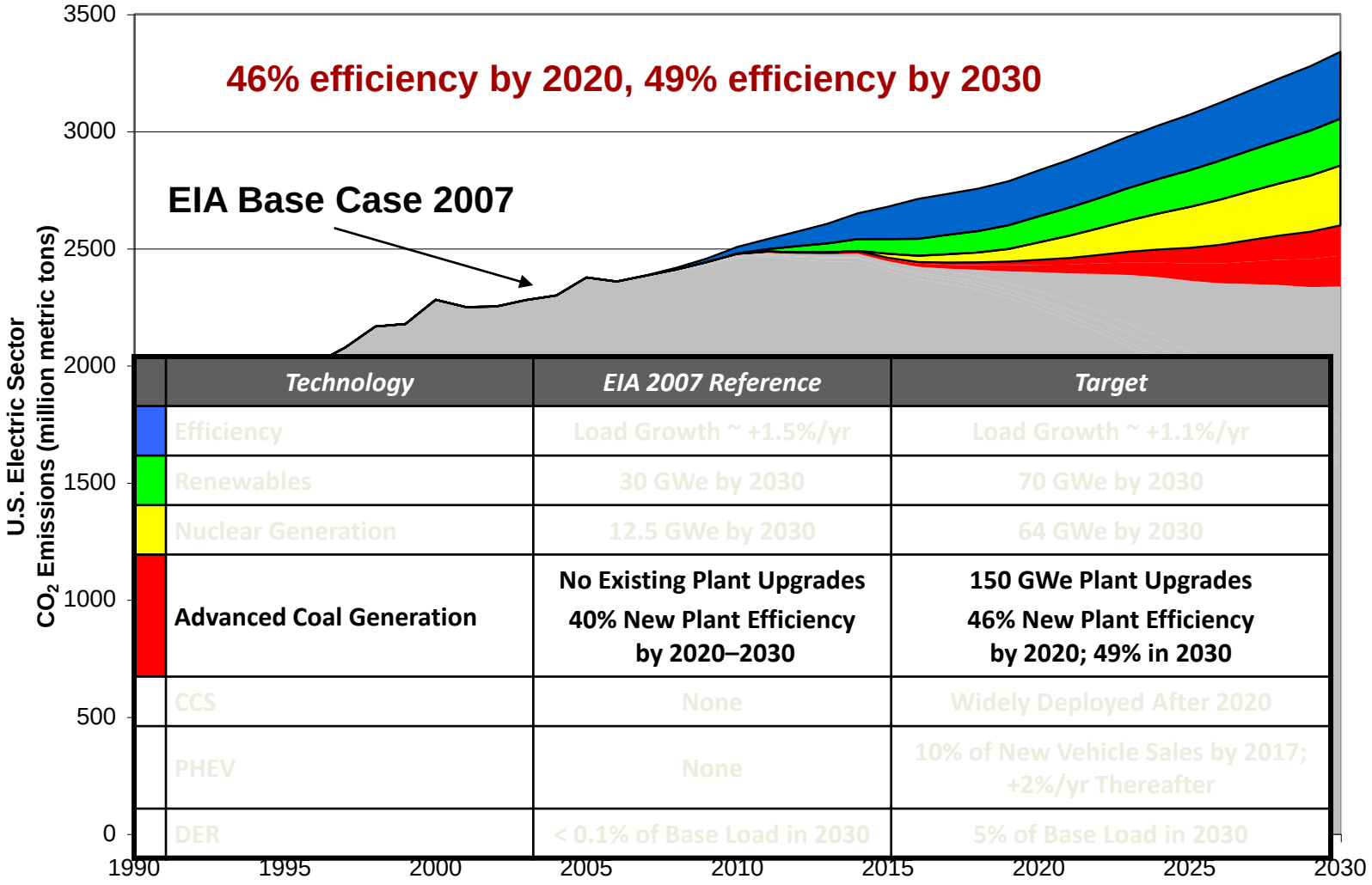
Benefit of Achieving Advanced Coal Generation Target



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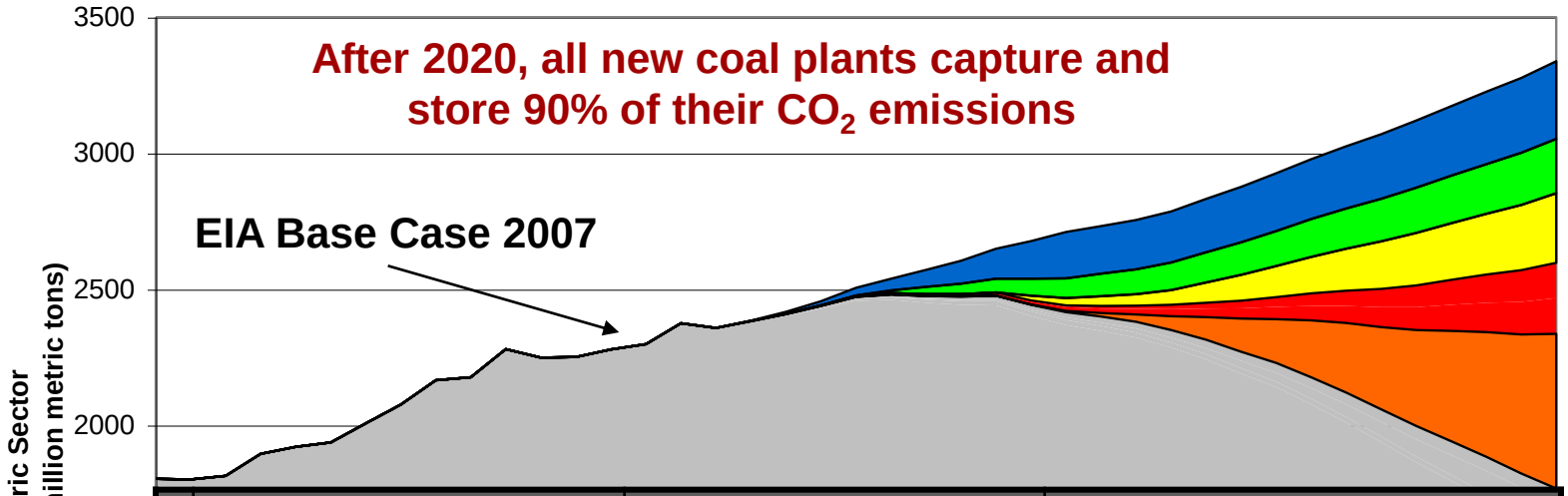
Benefit of Achieving the CCS Target



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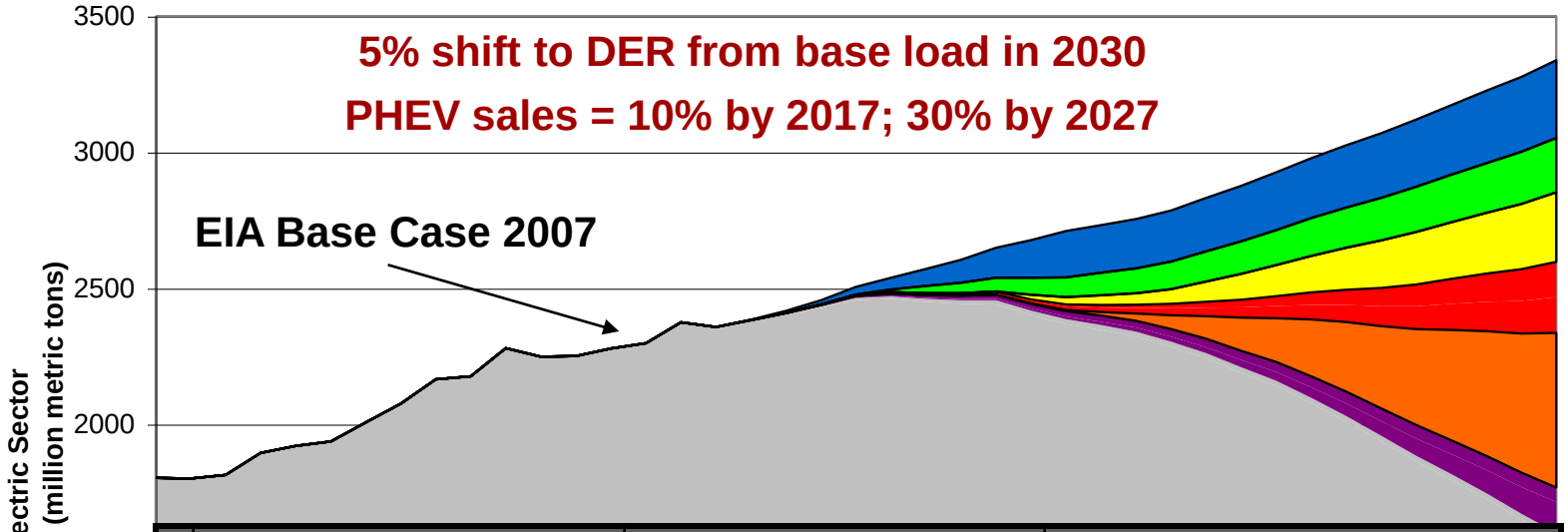
Benefit of Achieving PHEV and DER Targets



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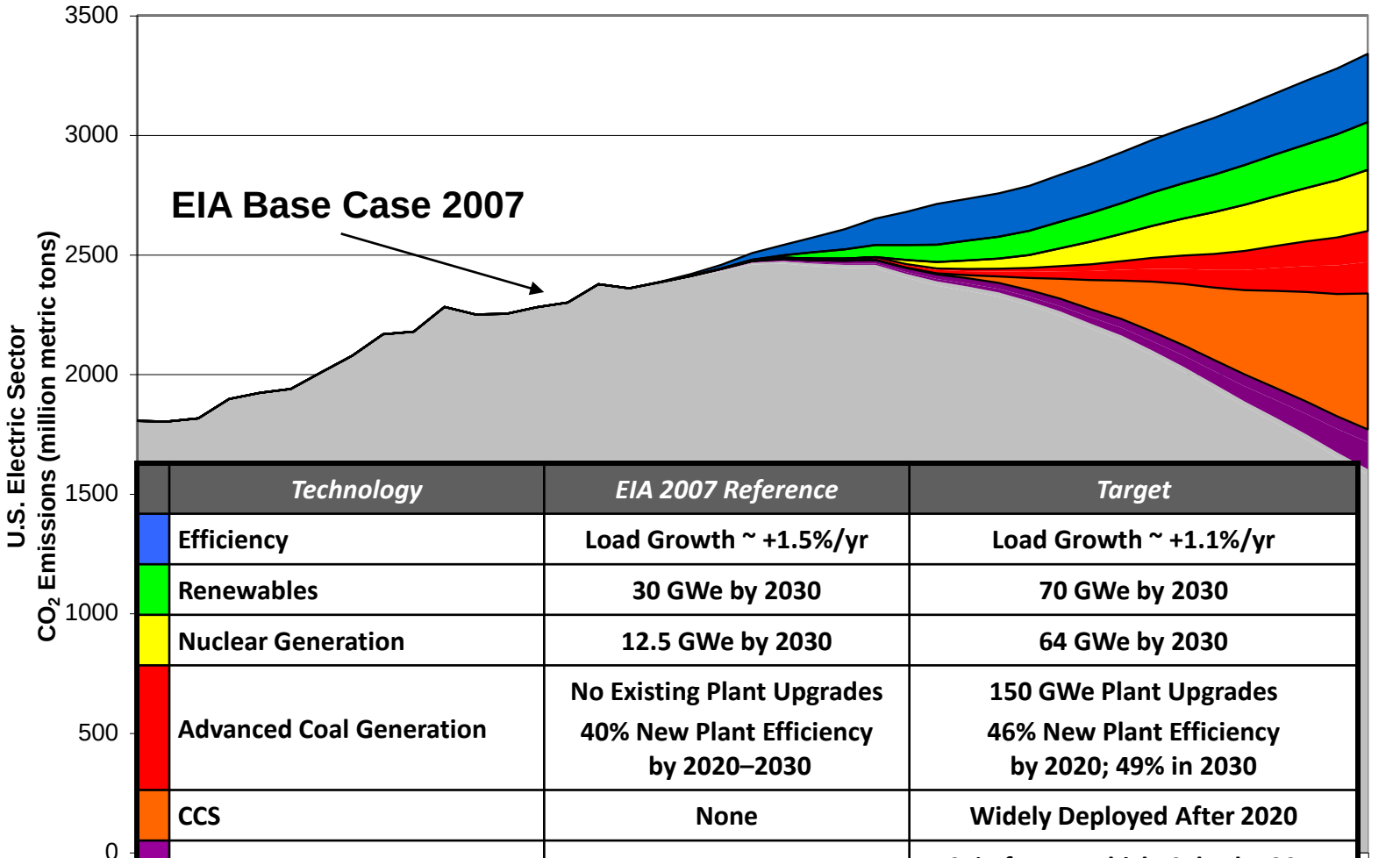
CO_2 Reductions … What's Technically Feasible



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Key Technology Challenges

The U.S. electricity sector will need ALL of the following technology advancements to significantly reduce CO_2 emissions over the coming decades:

1. **A grid infrastructure with the capacity and reliability to operate with 20-30% intermittent renewables in specific regions.**

2. **Significant expansion of nuclear energy enabled by continued safe and economic operation of existing nuclear fleet; and a viable strategy for managing spent fuel.**

3. **Commercial-scale coal-based generation units operating with 90+% CO_2 capture and storage in a variety of geologies.**

4. **Smart grids and communications infrastructures to enable end-use efficiency and demand response, distributed generation, and PHEVs.**

Energy Supply and Use

- Warming will be accompanied by decreases in demand for heating energy and an increasing demand for cooling energy.
- Energy production is likely to be constrained by rising temperatures and diminished water supplies.
- Energy production, transmission and distribution systems exposed to sea-level rise or extreme weather events will be vulnerable to disruption.
- Hydropower production will be affected by changing patterns of precipitation and snowmelt.

Climatic Effects on Energy

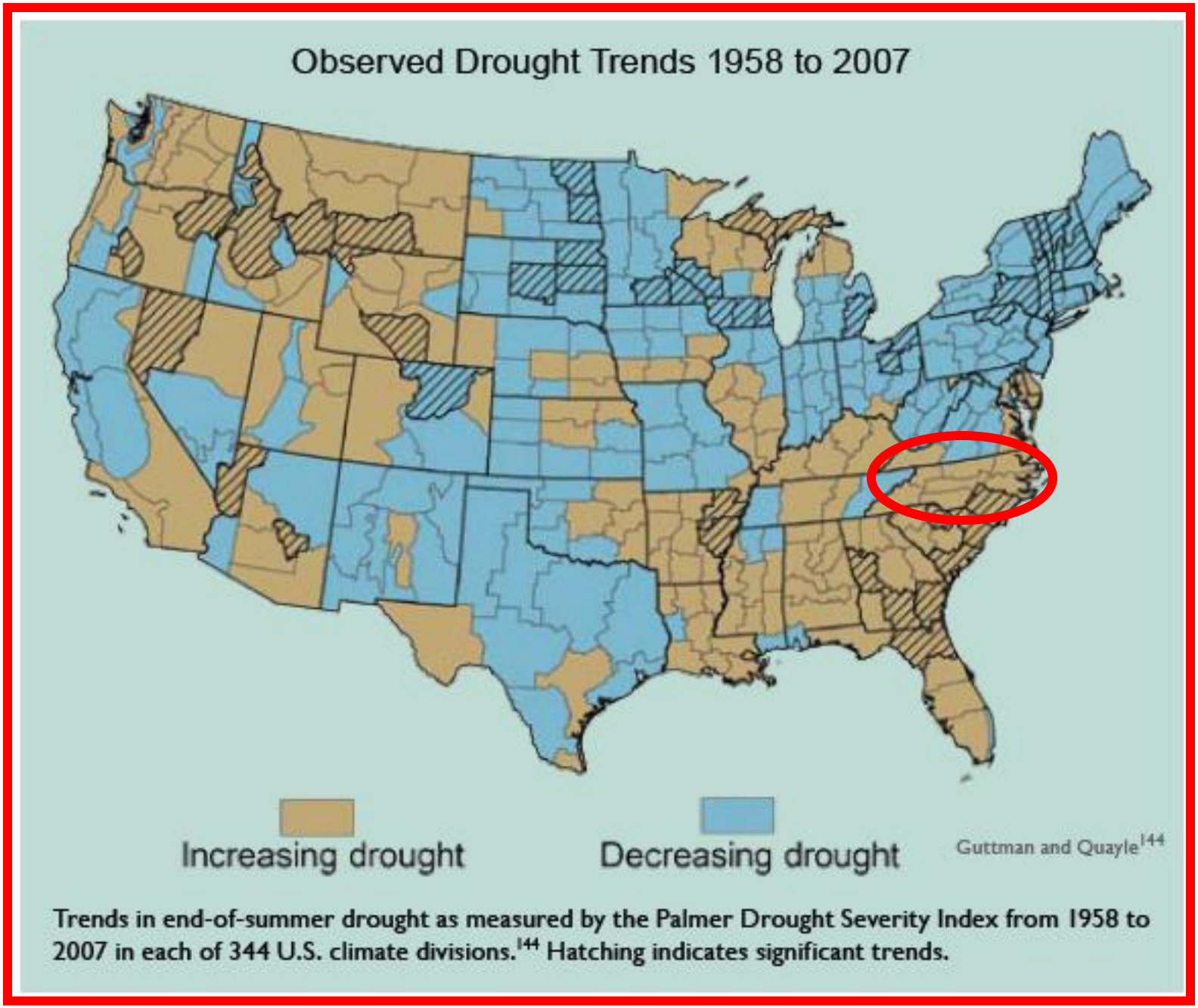
- Methane hydrates – harvest and use as energy source vs mitigate GHGs
- Warmer water less effective if providing coolant for thermoelectric power plants
- Change in the number of degree days for heating and cooling
- Efficiency losses in refinery and power plant operations

Cooling Tower and Evaporative Losses

Total Consumptive Water Use (gal/kWh)

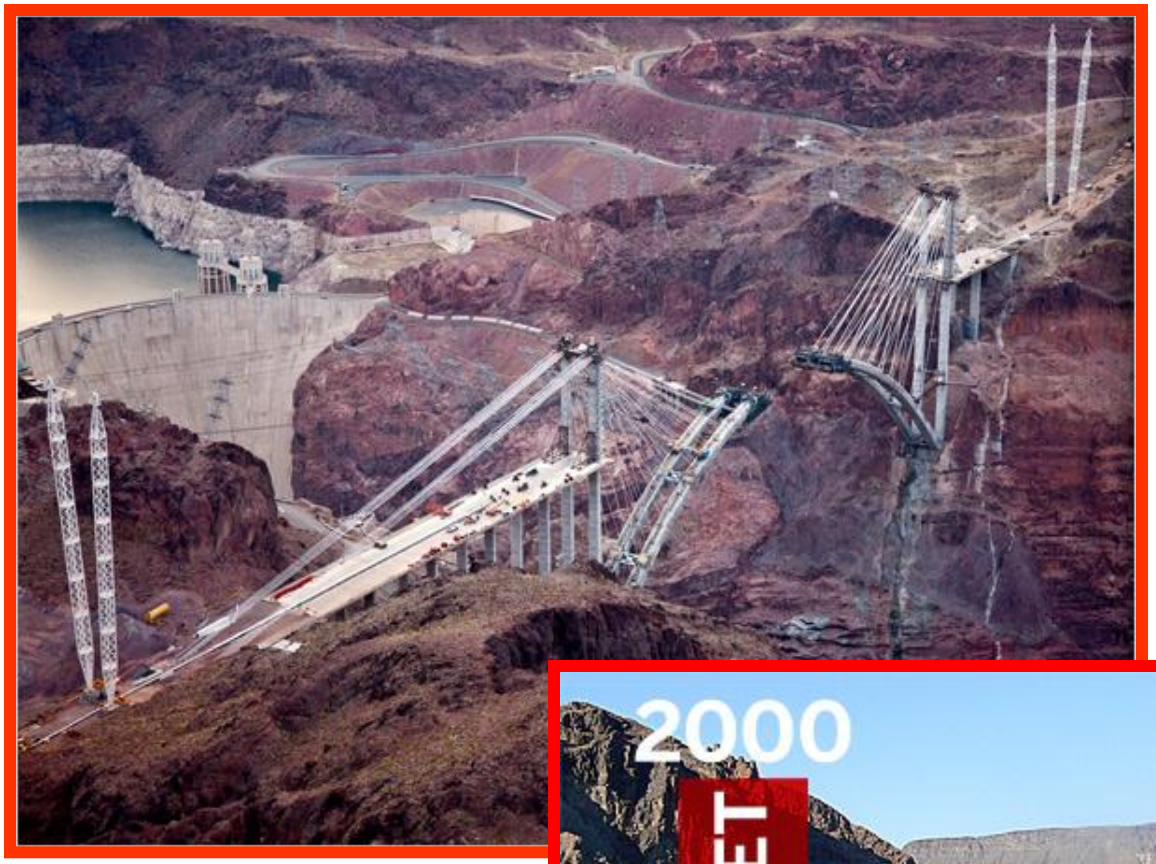
	Thermoelectric Site Water	Hydroelectric Site Water
NC	0.23	10.37
US	0.47	18.27

Observed Water-Related Changes During the Last Century[142]		
Observed Change	**Direction of Change**	**Region Affected**
One to four week earlier peak streamflow due to earlier warming-driven snowmelt	Earlier	West and Northeast
Proportion of precipitation falling as snow	Decreasing	West and Northeast
Duration and extent of snow cover	Decreasing	Most of the United States
Mountain snow water equivalent	Decreasing	West
Annual precipitation	Increasing	Most of the United States
Annual precipitation	Decreasing	Southwest
Frequency of heavy precipitation events	Increasing	Most of the United States
Runoff and streamflow	Decreasing	Colorado and Columbia River Basins
Streamflow	Increasing	Most of East
Amount of ice in mountain glaciers	Decreasing	U.S. western mountains, Alaska
Water temperature of lakes and streams	Increasing	Most of the United States
Ice cover on lakes and rivers	Decreasing	Great Lakes and Northeast
Periods of drought	Increasing	Parts of West and East
Salinization of surface waters	Increasing	Florida, Louisiana
Widespread thawing of permafrost	Increasing	Alaska



Trends in end-of-summer drought as measured by the Palmer Drought Severity Index from 1958 to 2007 in each of 344 U.S. climate divisions.[144] Hatching indicates significant trends.

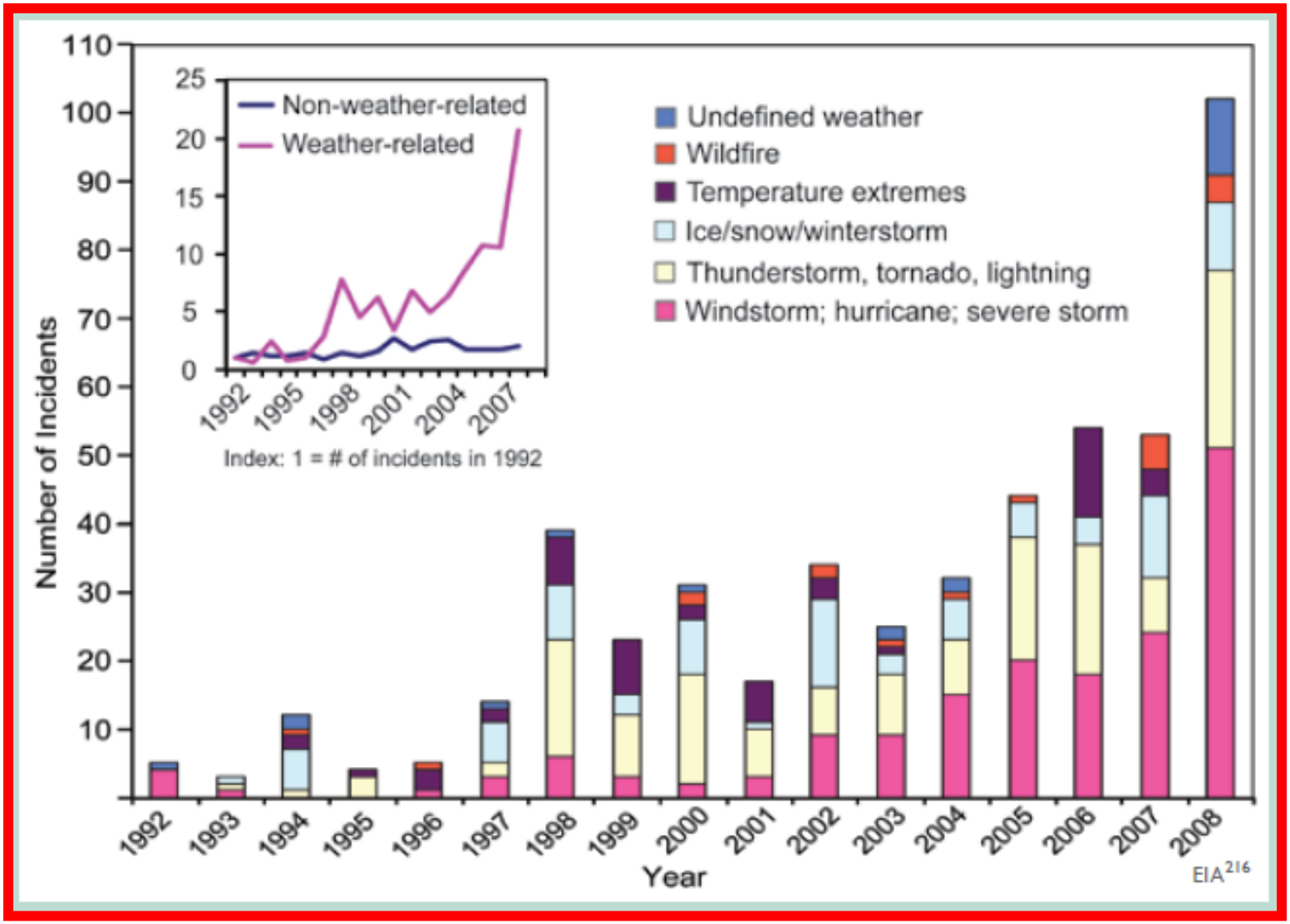
Hoover Dam and Lake Mead




1925
1955
SAN JOAQUIN VALLEY
CALIFORNIA
BM SS61
SUBSIDENCE BM
1925-1977
1977

Subsidence

Significant Weather-Related U.S. Electricity Grid Disturbances



Buildings

Consume 1/3
of the Earth's
Resources

Use 2/3
of the Electricity

Create 1/3
of the Earth's
Pollution

Adapting to Unavoidable Change

- Societal behavior modifications
  - Emphasis on efficiency and conservation measures
- Adaptive policies and regulations
- Technological fixes and innovation

Societal Behavior Modifications

- **develop a culture of energy consciousness**
- **change habits, lifestyles and technology-based behaviors**
- **changed behaviors might reduce household use of energy by about 20-30 percent over the next 5-8 years within the United States. (American Council for an Energy-Efficient Economy)**

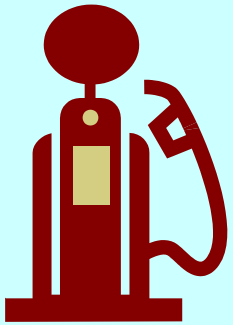
Virtual water content of products

1 cotton shirt	4000 litres
1 hamburger	2400 litres
1 cup of coffee	140 litres
1 glass of beer	75 litres
1 slice of bread	40 litres
1 sheet of A4-paper	10 litres

Source: Arjen Hoekstra, University of Twente, Netherlands

Adaptive Policies and Regulations

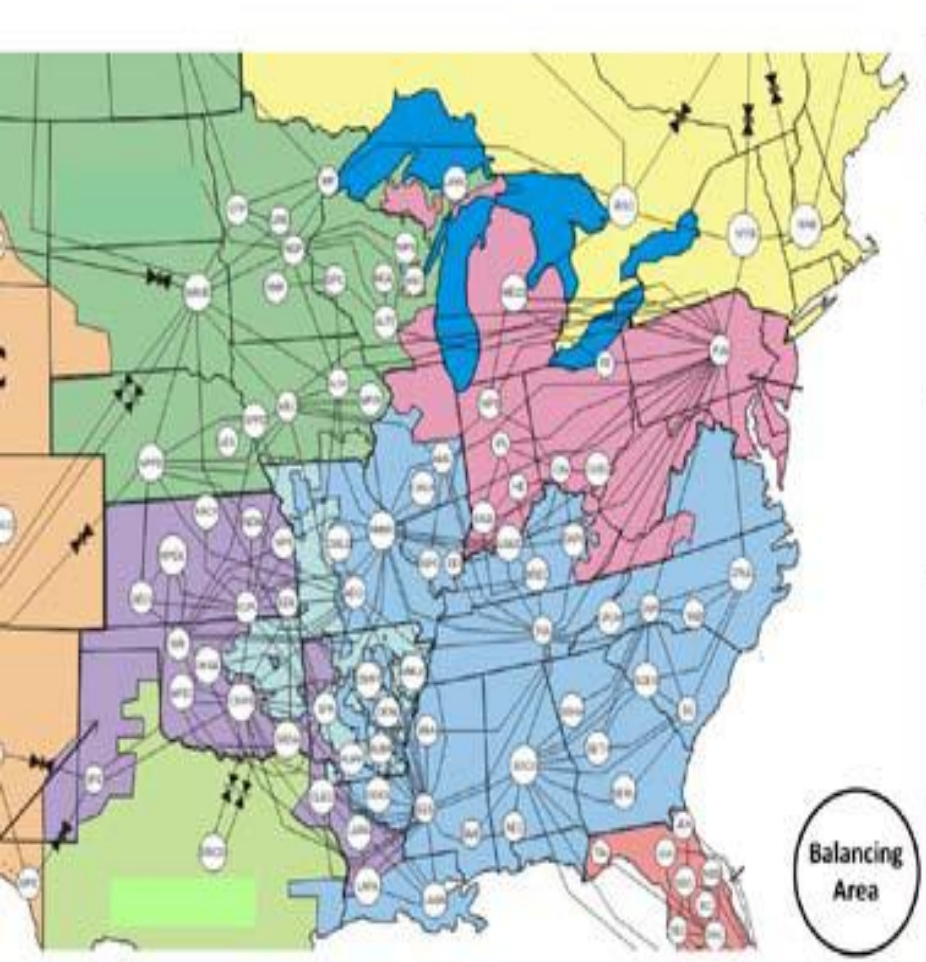
- Renewable Portfolio Standards (RPS)
- CAFÉ Standards
- $4.00/gallon gasoline
- Adapt to anticipated and unanticipated conditions
- Subsidies, tax incentives, loan guarantees.



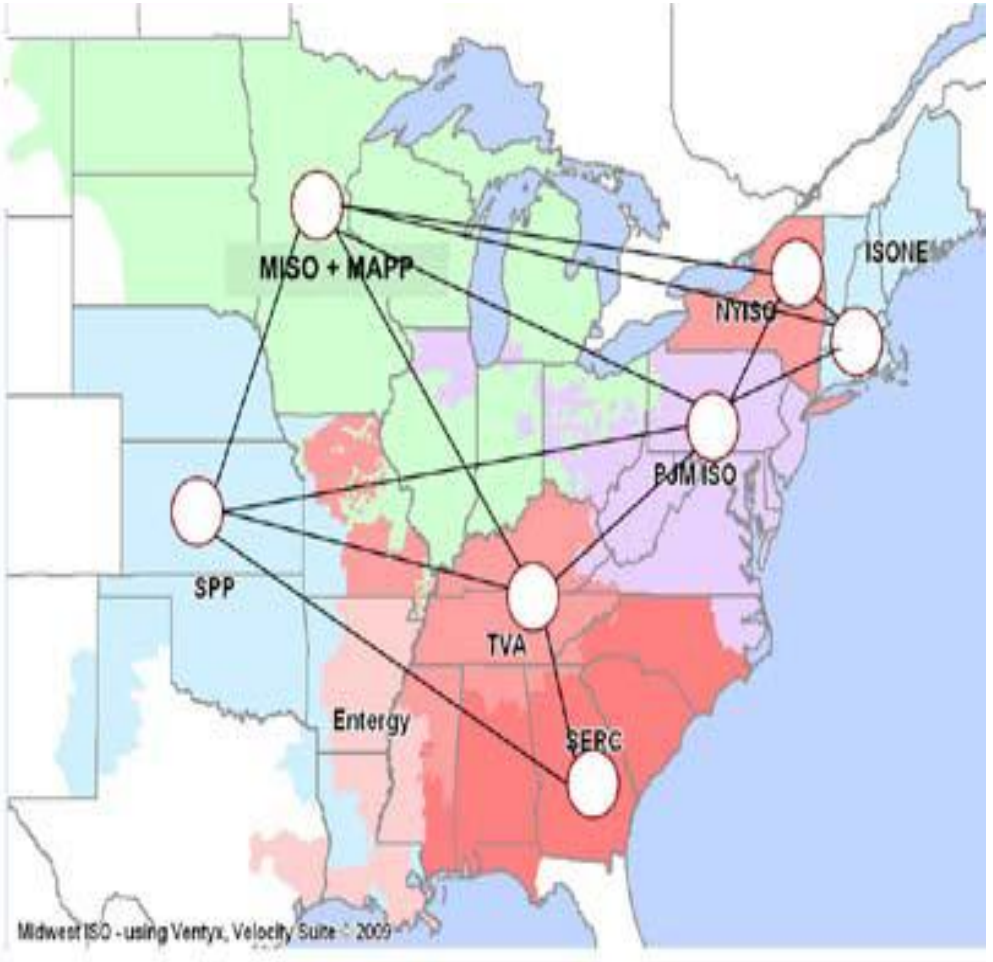
Technological Fixes/Innovation

- Industrial ecology
- "Smart technology (e.g., grid, metering, appliances, household management systems)
- Colocation of complementary facilities
- Alternative sources of cooling water and cooling methods
- Technology transfer and outreach (foreign investments?)

Assumed operational structure for the Eastern Interconnection in 2024 (white circles represent balancing authorities)



Balancing Area

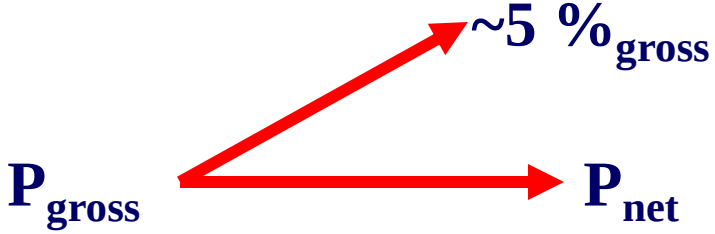


As of August 1, 2007

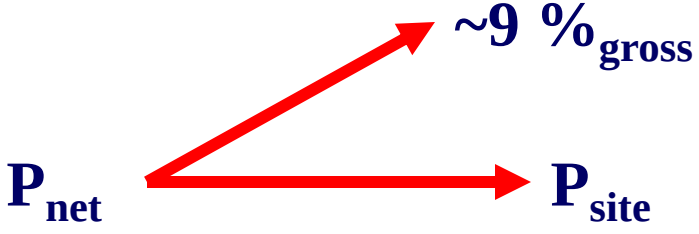
Assumption for 2024

Thermoelectric Power Plants

Power Plant Use



Transmission/ Distribution Losses

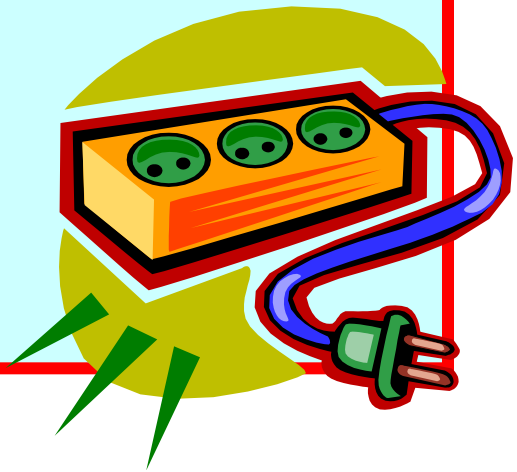


Weatherize	Reduce phantom loads	Run appliances after midnight	Add insulation
Use cold water to wash/rinse clothes	Use clothes line for drying laundry	Use microwave instead of oven	Run dishwater only when full
Defrost freezer	Lower AC temperature	Raise furnace temperature	Turn off lights not in use
Reduce water heater temperature	Reduce refrigerator temperature	Take shorter showers	Turn off water while brushing teeth and shaving

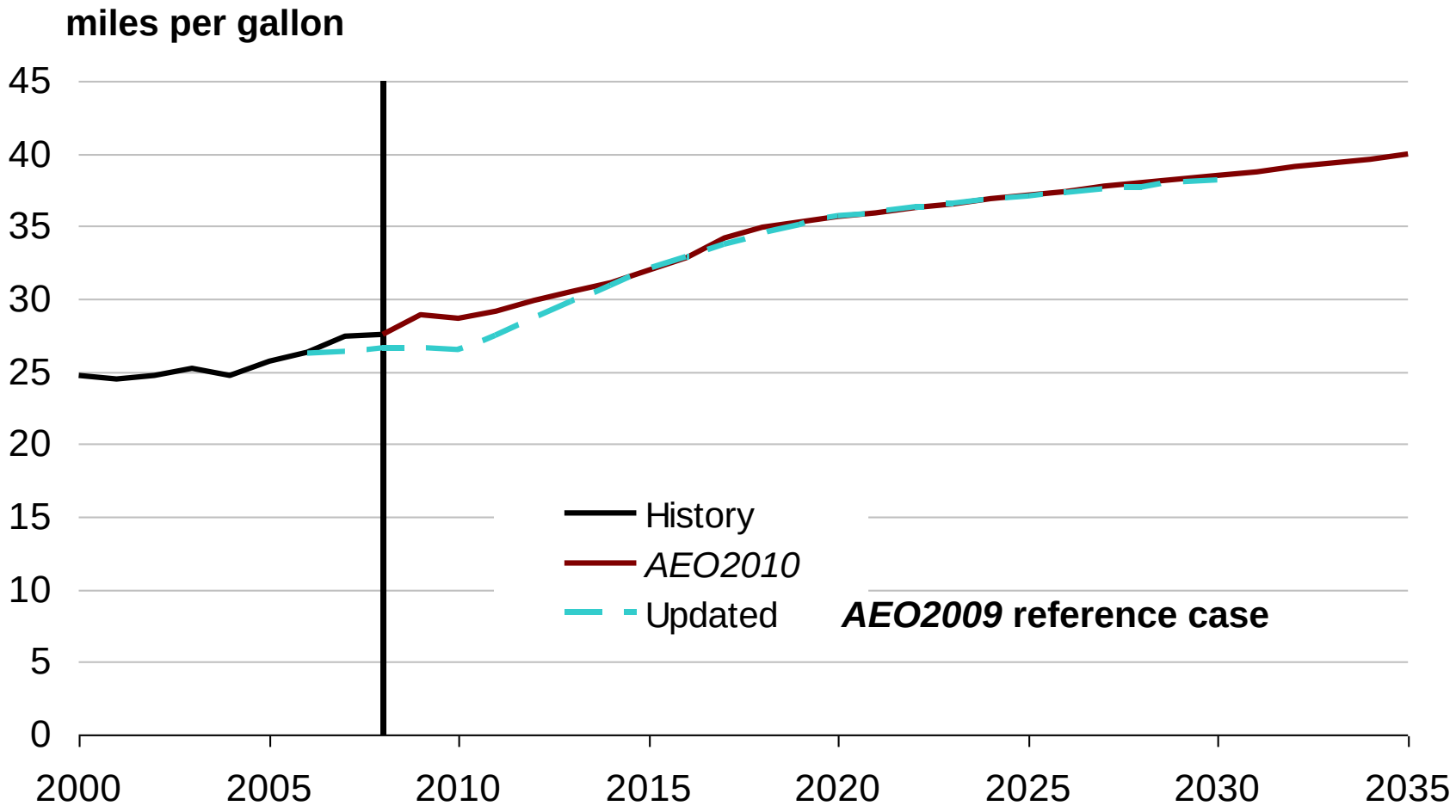
Reduce Household Energy Consumption

Phantom Load Power Consumption Examples

Electrical device	Load (Watts)
Microwave	2-6
Answering machine	2-3
Cordless phone	2-4
CD player	3-8
TV	0-12
VCR	1-15
Oven clock	3-4
Security system	6-22
Cable box	8-15
Computer	0-2



New light duty vehicle efficiency reaches 40 mpg by 2035



Source: *Annual Energy Outlook 2010*

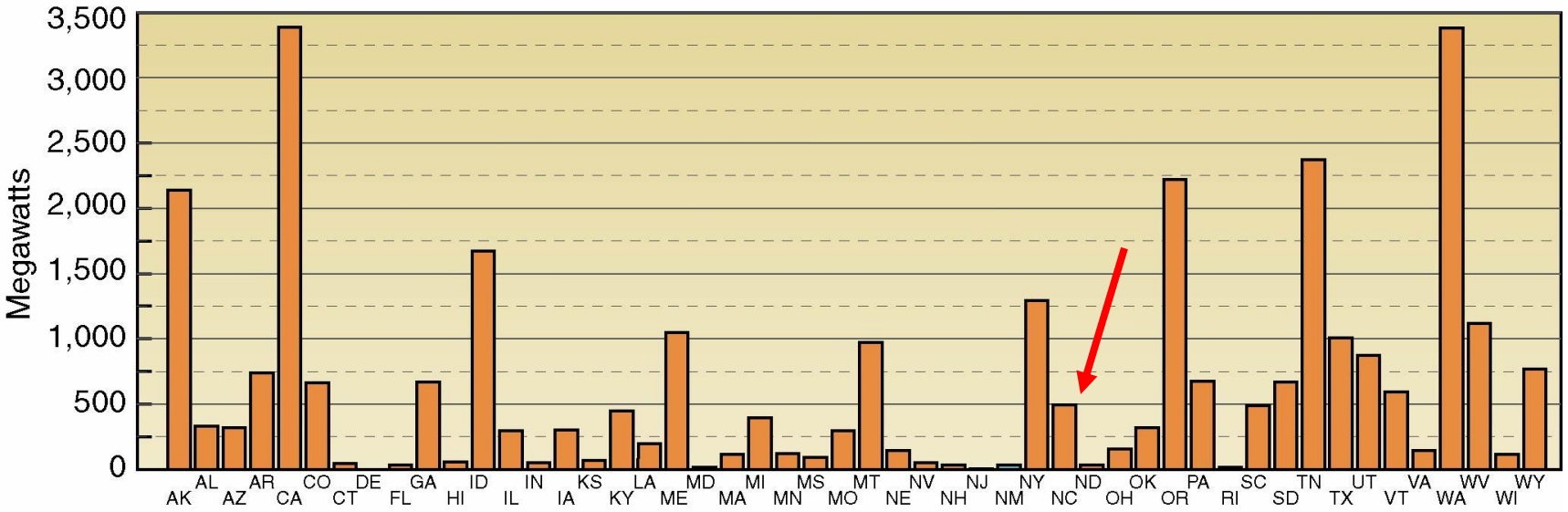
Combine errands	Idle < 10 seconds	Maintain vehicle	Properly inflate tires
Maintain proper speed	Don’t rev engine	Discard excess weight	Install smart signals
Reduce or eliminate 4-way stops	Anticipate Traffic stops	Car pool or eliminate travel	Install traffic circles
Use alternative mode:	Public, bike or walk	Biofuels	PHEVs

Adaptive Responses: Liquid Fuels

Adaptation

Green house gases can be significantly reduced when appropriate enzymes are used in production processes. Literally 10s to 1,000s of Kg/ton of product of GHGs can be eliminated in the production of ethanol, cheeses, breads, detergents, cosmetics, paper . . . . .

Uneven Resource

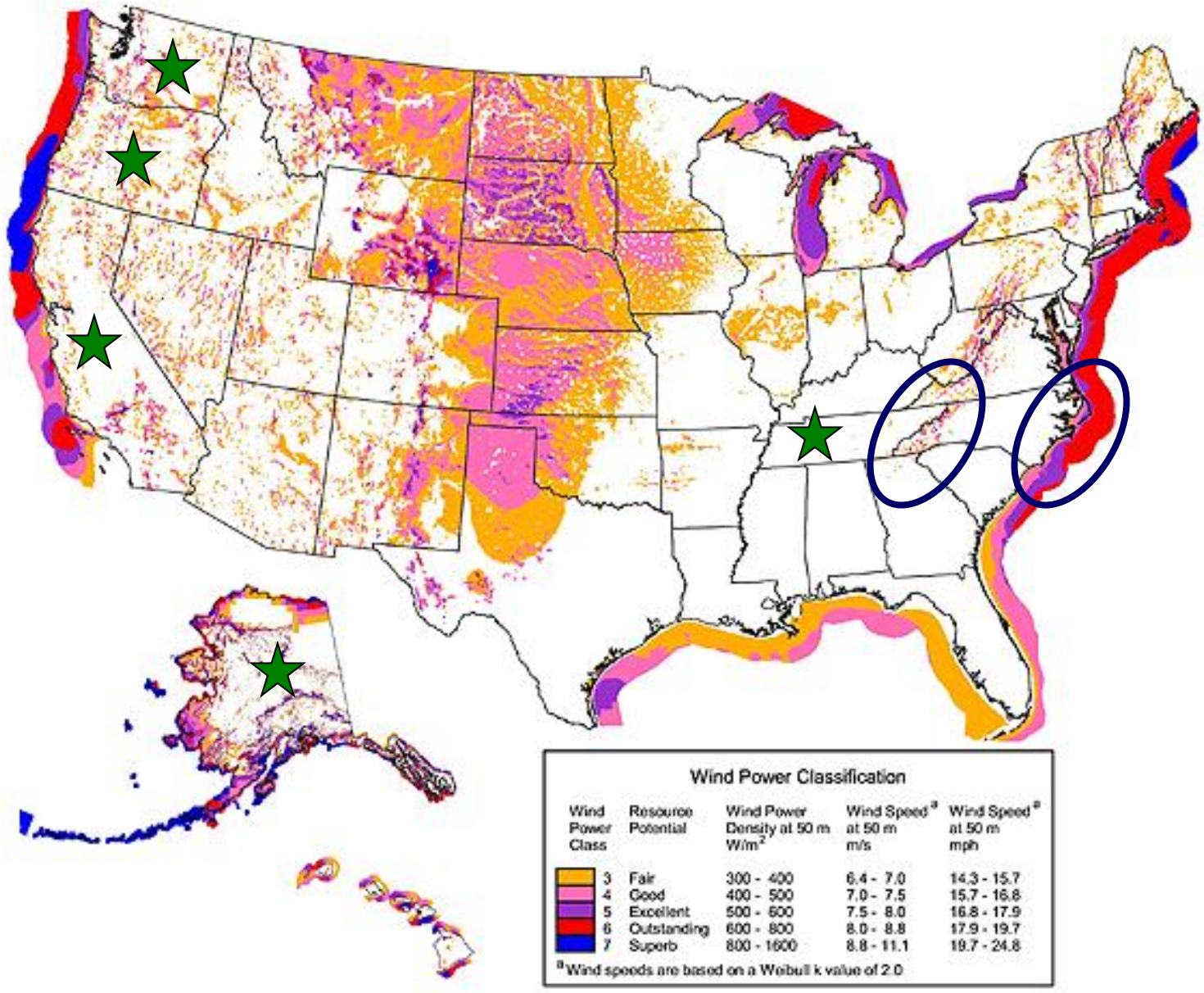


Source: Hydroelectric Power Resources Assessment database (FERC) and Hydropower Evaluation Software (INEEL). DOE has modeled the undeveloped conventional hydropower potential in the United States. This does not include developed capacity. Various state agencies have reviewed the modeled results and provided input. The 50-state undeveloped conventional hydropower potential is approximately 30,000 MW. The model includes environmental, legal, and institutional constraints to development.

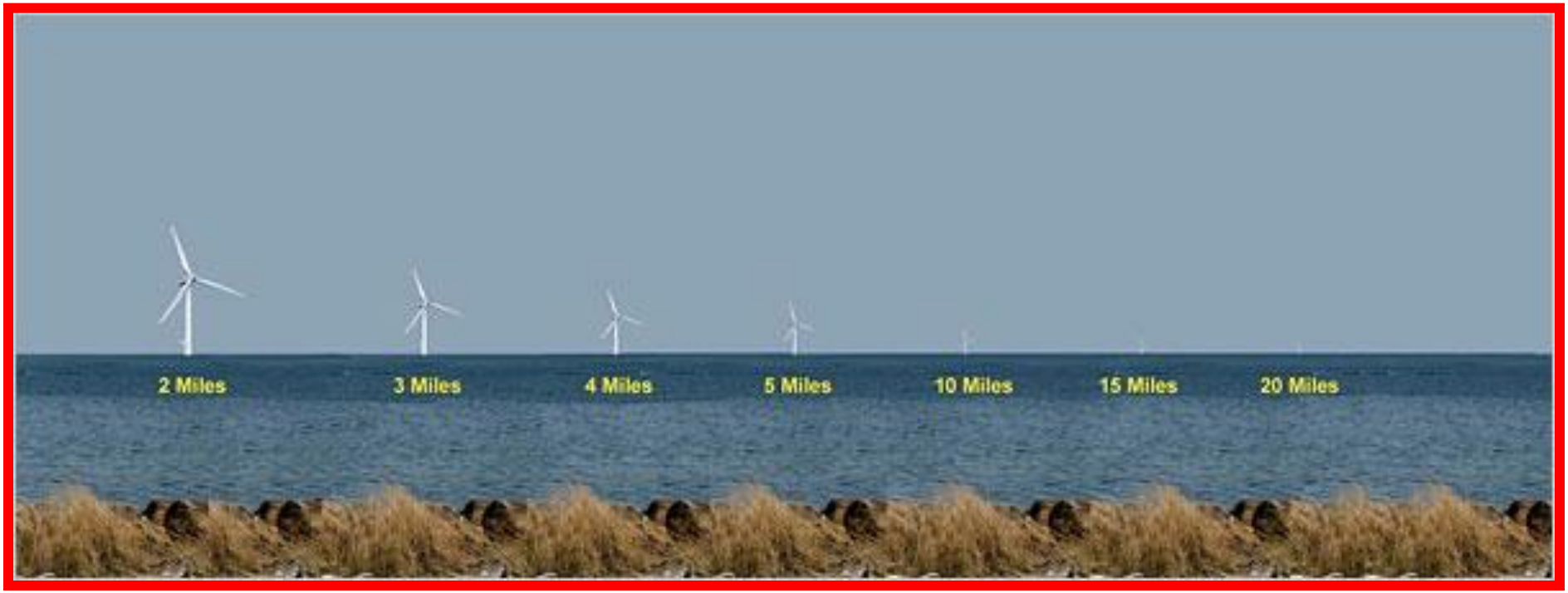
Diversion

- Small scale power generation
- Diverts a portion of natural river flow for energy generation
- Reduced environmental impact compared to impoundment

Wind Resources



Architectural Wind


2 Miles
3 Miles
4 Miles
5 Miles
10 Miles
15 Miles
20 Miles

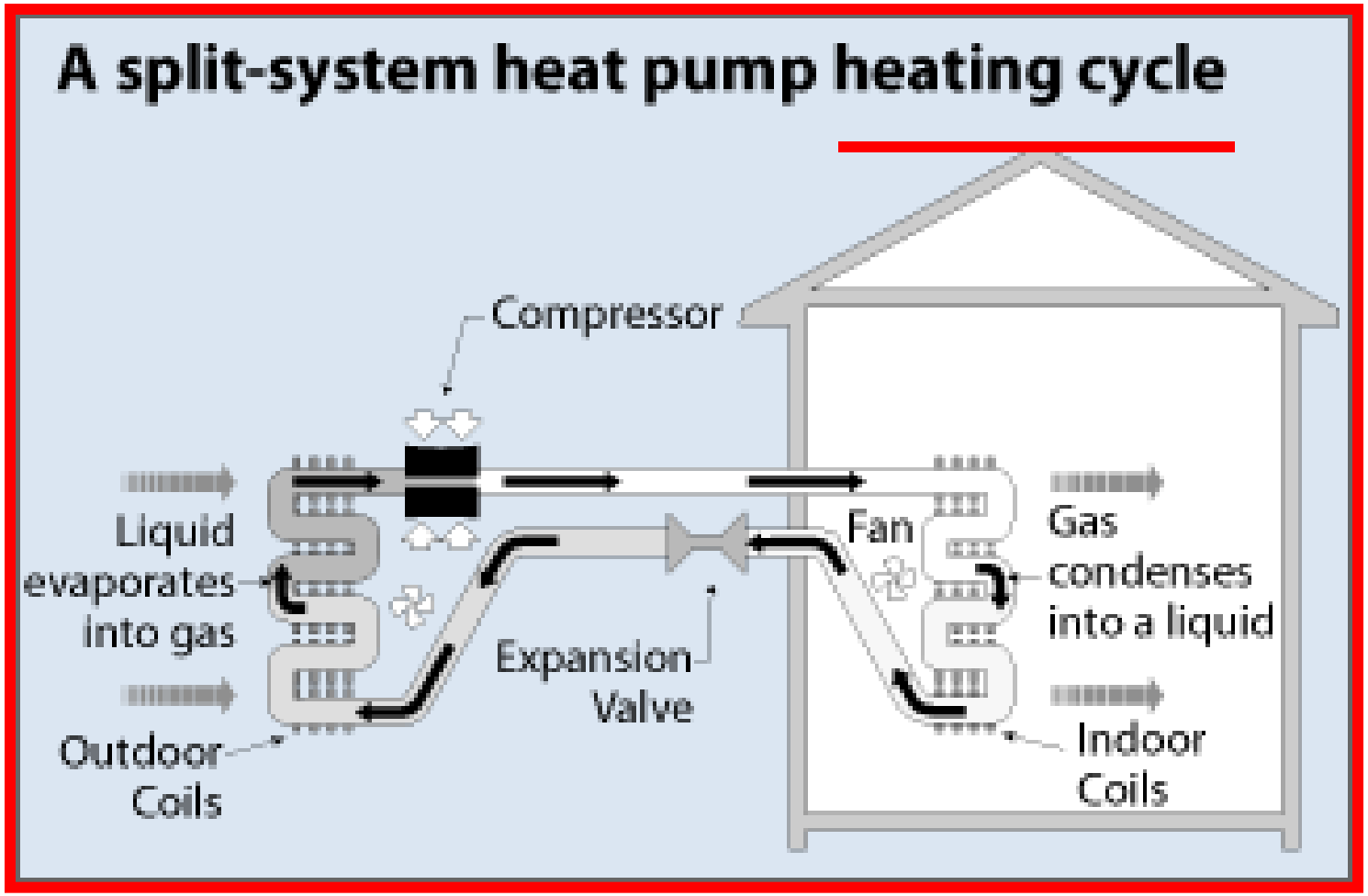
Areas with adequate wind are valuable and popular

- Great Plains
- Coastlines
  - Martha's Vineyard, Outer Banks,
  - Texas Gulf, Great Lakes,
  - Pebble Beach, Big Sur, Catalina
- Mountain passes
  - Appalachian Trail, Great Smokies, Glacier, Grand Tetons

Ocean Energy

- Waves, Currents
- Tides
- Ocean Thermal Energy Conversion (OTEC)

Air-Source Heat Pump



Also ground-source heat pumps

POGO:

WE HAVE MET THE ENEMY AND HE IS US

Walt Kelly